Experimental Demonstration of GPON/XGS-PON Combo PON Repeater extending coverage and PON capacity

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Abstract *We successfully demonstrate the extension of service coverage for PON system through the use of combo PON repeater. Transmission distance of 55 km and 128-way split is achieved and stable operation of packet throughput of 8 Gbps in both directions over 72 hours is verified.*

Introduction

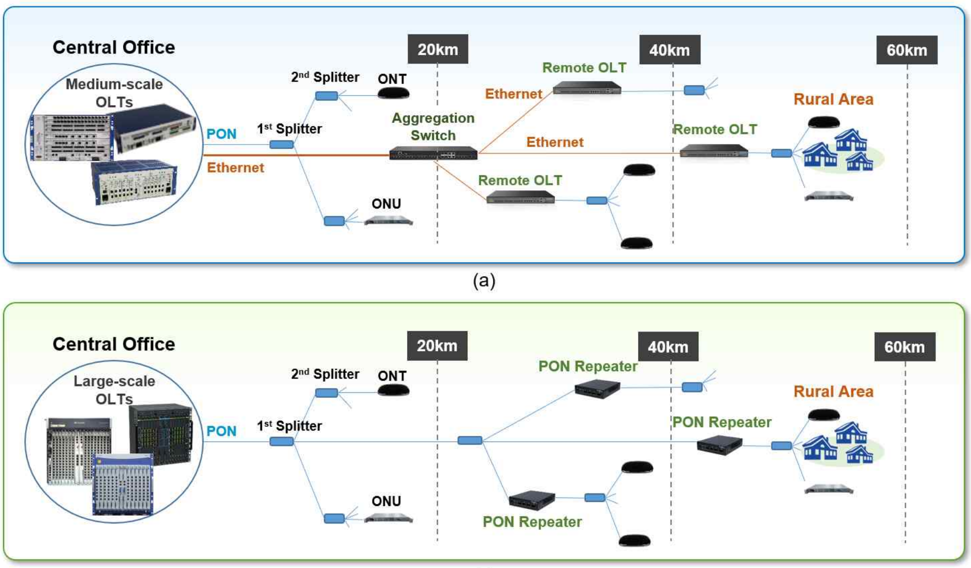
PON is commonly used to provide broadband services in optical access networks within a 20 km range based on a link budget of 29 dB [1-2]. To expand the coverage of PON services, network operators often use remote OLTs in subscriber areas [3]. As shown in Fig. 1(a), these remote OLTs are connected to the central office through an Ethernet network, which requires multiple aggregation switches. As a result, the optical access network becomes complex with a combination of PON and Ethernet networks, leading to increased operational expenses (OPEX) and capital expenses (CAPEX).

If PON repeaters are used to extend PON service coverage, the broadband services can be easily provided to subscribers in rural areas through the same PON. Additionally, we could expand service coverage to accommodate a large number of subscribers. To ensure a smooth migration to higher speed PON, such as GPON and XGS-PON, these OLT platforms can be accommodate over a single ODN. However, only single speed PON repeaters such as GPON and EPON are available by off-the-self equipment [4].

In this paper, we experimentally demonstrate GPON/XGS-PON combo PON repeater that can provide long-distance transmission services for simultaneously through a single ODN. The combo PON repeater can extend the transmission distance of the existing GPON and XGS-PON system up to 55 km on a 128-way split. We also confirm that packet performance of 8 Gbps in both directions is guaranteed with no packet loss over 72 hours.

Architecture of combo PON repeater

Fig. 2 shows the extended PON structure based on the combo PON repeater. This technology allows for the simultaneous accommodation of both GPON and XGS-PON subscribers in a single ODN through the use of an external CE1 (Coexistence Element 1) module or combo OLT optical transceiver [5]. The combo PON repeater is utilized to extend the optical transmission distance in a combo PON system and can be installed between the OLT and ODN, or between the ODN and ONUs. The proposed combo PON repeater is designed as an OEO-type and



(a)

(b)

Fig. 1: Method of PON service coverage extension (a) using remote OLT (b) using PON repeater

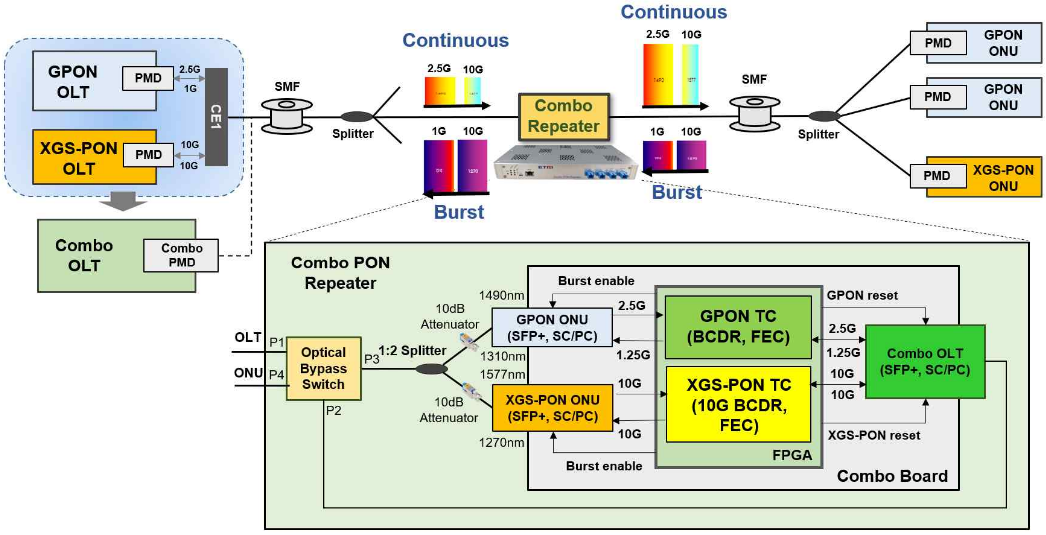


Fig. 2: Structure of extended PON based on combo PON repeater

consists of a GPON and XGS-PON ONU optical transceiver, a single FPGA for detecting and restoring burst mode signals, and a combo OLT optical transceiver. It supports downstream transmission rates of 2.48 Gbps and 9.95 Gbps, and upstream transmission rates of 1.24 Gbps and 9.95 Gbps. The GPON and XGS-PON ONU optical transceivers are connected to each OLT equipment through a 1:2 optical splitter, with a 10dB attenuator inserted to reduce the interference from optical signals reflected by the splitter. The combo OLT optical transceiver detects burst mode optical signals from the GPON and XGS-PON based on reset signals provided by the FPGA, and then transmits to the ONUs. The FPGA extracts the upstream bandwidth map (BWmap) field from the downstream PON frame to provide an accurate burst mode reset signal. To achieve this, transmission convergence (TC) layer functions of ONU and OLT are implemented within FPGA. Additionally, an FEC function is applied to obtain error-free transmission.

The operation of the combo PON repeater is as follows. In downstream direction, each ONU optical transceiver converts the OLT optical signal received from 1:2 splitter into an electrical signal. The FPGA then extracts the upstream bandwidth map from the PON frame and transmits the electrical signal back to the combo OLT optical transceiver. Lastly, it converts each electrical signal received from FPGA into an OLT optical signal. In the upstream direction, the combo PON repeater receives burst mode optical signals transmitted from ONUs based on the bandwidth map. The FPGA provides a reset signal to the combo OLT optical transceiver before the burst mode optical signal arrives, based on the bandwidth map. The burst mode PON frame is then extracted by performing a delimiter search in the burst mode CDR. This extracted frame is regenerated by adding the preamble and delimiter and then transmitted to each ONU optical transceiver. Finally, the ONU optical transceiver converts the burst mode electrical signals into optical signals and transmits them to each OLT through the 1:2 splitter.

The bypass optical switch is optional and can be used to send input optical signal in the OLT port (i.e., P1) directly to ONU port (i.e., P4) when the power supply is cut off. The proposed combo PON repeater is capable of satisfying the timing drift tolerance of ±8 bits and ±32 bits in GPON and XGS-PON, respectively.

Experimental setup and results

Fig. 3(a) shows the experimental setup for the demonstration of combo PON repeater with GPON and XGS-PON OLT/ONUs at 55 km distance with 1:128 split ratio. To achieve this, we configured a transmission distance of 40 km using two 20 km SMF and CE1 module in the feeder section (between OLT and combo PON repeater). Additionally, we configured a 15 km reach and 1:128 split ratio through a 15 km SMF and multi-stage splitters in the ODN section (between combo PON repeater and the ONUs). As shown in Fig.3(a), we used 15 GPON ONUs and 20 XGS-PON ONUs for a more detailed real-time demonstration. And we used 15 GPON ONUs and 20 XGS-PON ONUs for more detailed real-time test verification. Fig. 3(b) shows the real-time verification environment of the combo PON repeater.

Fig. 3(c) shows the results of GPON ONUs registered to the OLT through combo PON

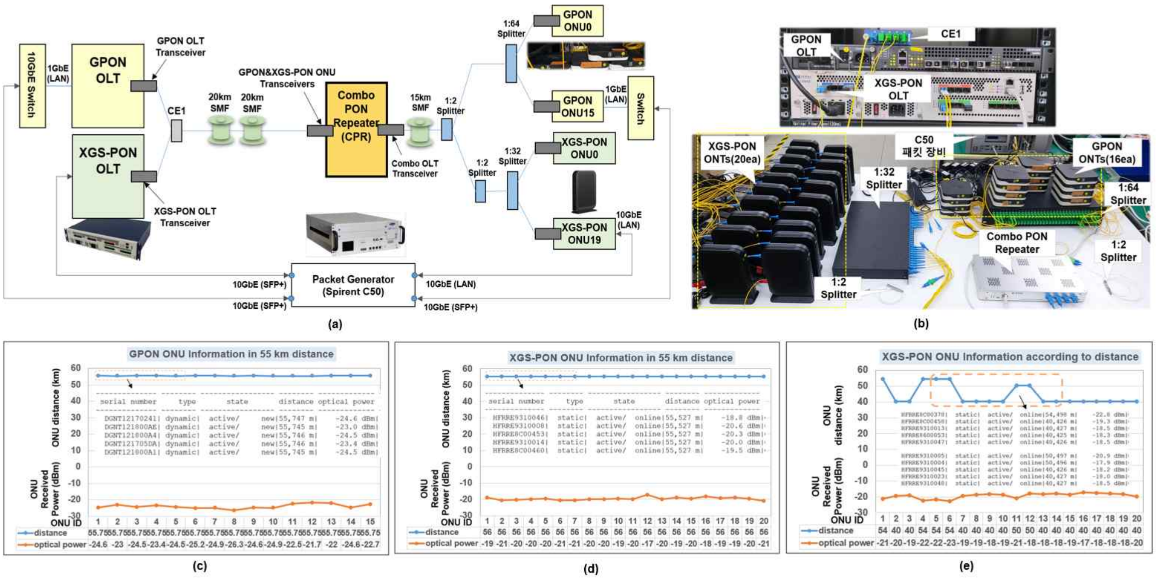


Fig. 3: Expeimental setup and results (a) demonstration setup; (b) real-time demonstration screenshot; (c) GPON ONU information results in 55 km distance; (d) XGS-PON ONU information results in 55 km distance; (e) XGS-PON ONU information results in ranging from 40 km to 55 km

repeater at 55 km. From this result, we can confirm that the distance of all ONU is measured to be approximately 55.7 km. The received optical power in the GPON ONUs has a deviation of about 4.6 dB, ranging from a maximum of -21.7 dBm to a minimum of -26.3 dBm, with an average optical power of -23.96 dBm. Fig. 3(d) shows the result of XGS-PON ONUs registered to the OLT at the same distance. Distance of all ONU is measured to be about 55.5 km with a deviation of about 3.8 dB. And average optical power is measured to be -19.53 dBm.

Fig. 3(e) shows the results of XGS-PON ONUs registered to the OLT with ranges from 40 km to 55 km. For this, we reconfigured the ODN section. ONUs located at 40 km range were directly connected to 128-way split without SMF, while ONUs located 50 km range were connected by a 10 km SMF and 128-way split. In this result, we can confirm that ONU distance was variously measured at 40 km, 50 km and 55 km.

Stream Block	Tx Count (Frames)	Rx Count (Frames)	Dropped Count (Fram...	Tx Rate (Mbps)	Rx Rate (Mbps)
OLT --> ONU1	21,371,615,088	21,371,632,220	0	652.77	652.82
OLT --> ONU2	21,371,615,088	21,371,632,235	0	653.38	653.58
OLT --> ONU3	21,371,615,088	21,371,632,436	0	653.83	653.68
OLT --> ONU4	21,371,615,088	21,371,632,517	0	653.79	653.51
OLT --> ONU5	21,371,615,088	21,371,632,371	0	653.82	653.81
OLT --> ONU6	21,371,615,088	21,371,632,259	0	652.95	652.86
OLT --> ONU7	21,371,615,088	21,371,632,502	0	652.42	652.31
OLT --> ONU8	21,371,615,088	21,371,632,339	0	652.39	652.43
OLT --> ONU9	21,371,630,244	21,371,632,418	0	652.41	652.43
OLT --> ONU10	21,371,630,244	21,371,632,429	0	653.19	653.21
OLT --> ONU11	21,371,630,244	21,371,632,266	0	652.98	653.01
OLT --> ONU12	21,371,630,244	21,371,632,344	0	652.5	652.59
ONU1 --> OLT	21,182,572,239	21,182,573,852	0	646.98	646.89
ONU2 --> OLT	21,182,579,220	21,182,580,802	0	646.83	646.57
ONU3 --> OLT	21,182,575,393	21,182,576,987	0	646.89	646.94
ONU4 --> OLT	21,182,577,494	21,182,579,061	0	646.84	646.87
ONU5 --> OLT	21,182,565,316	21,182,576,638	0	646.88	646.83
ONU6 --> OLT	21,182,558,997	21,182,570,377	0	646.9	646.88
ONU7 --> OLT	21,182,559,758	21,182,571,141	0	646.92	646.93
ONU8 --> OLT	21,182,561,932	21,182,573,300	0	646.89	647.17
ONU9 --> OLT	21,182,564,978	21,182,576,019	0	646.88	647.02
ONU10 --> OLT	21,182,566,757	21,182,577,722	0	646.86	646.74
ONU11 --> OLT	21,182,561,491	21,182,572,480	0	646.89	646.95
ONU12 --> OLT	21,182,562,806	21,182,573,804	0	646.91	646.89

Fig. 4: Packet test results in XGS-PON via combo PON repeater

Fig. 4 shows the results of measured packet transmission performance over 72 hours using packet generator (Spirent C50). For this demonstration, packets were input to the OLT at a speed of 8 Gbps, and then packets of 660 Mbps were applied to each of 12 ONUs. The test showed no packet drops during variable length packet transmission.

Conclusions

We have experimentally demonstrated the extended combo PON service using a combo PON repeater to accommodate GPON and XGS-PON subscribers in a single ODN. Real-time measurements over a 55 km reach and 1:128 splitter show that GPON and XGS-PON ONUs are successfully accommodated by combo PON repeater, which confirms the extended coverage and guaranteed PON capacity.

Acknowledgements

This work was supported by IITP grant funded by the Korea government (MSIT) [2019-0-00452, High speed optical access and slicing technology for B5G]

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